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Energy, economic, and social impacts of a clean energy economic policy: Fuel cells deployment in Delaware

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A R T I C L E I N F O

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A B S T R A C T

Clean energy-related economic policy is designed to promote new energy technology and vigorous economic development. However, this type of policy is typically implemented and evaluated separately in the economic and energy sectors: comprehensive assessments are rarely done. This study analyzes the policy effectiveness of a clean energy-related economic policy in Delaware from energy, economic, and social perspectives.

In 2011, the Delaware government provided generous economic incentives to attract California-based Bloom Energy to establish a fuel cell industry in the state. After eight years of operation, Bloom's fuel cells demonstrated high-efficiency performance (45%). However, the company has not met the goals of job creation and payroll additions that it had promised to the Delaware government. In addition, public debate has arisen regarding the Qualified Fuel Cell Provider Project (QFCP), a special tariff for Bloom Energy.

This paper concludes that when a government provides economic incentives to support new technology development, public acceptance should also be considered, particularly when the policy brings long-term social obligations and effects. Cost-sharing equity, decision making transparency, and knowledge enhancement are issues. Lessons learned from this case are applicable to a broader context.

1. Introduction

Innovative clean energy technologies open a window for aligning low-carbon energy transition with economic revitalization. Recognizing the growing benefits brought by clean energy, two dozen United States (U.S.) governors emphasized boosting the local economy through clean energy deployment in their 2012 state-of-the-state addresses (National Governors Association, 2014). The federal government also has shaped clean energy industries through regulatory, trade, tax, and other policies. All these efforts have strongly influenced the demand for clean energy products and services in the United States (Hart, 2019a). Energy and the economy were traditionally addressed by separate agencies that had distinct goals and policies. Synchronizing economic and energy policies through utilizing clean energy technologies is an emerging trend. The effectiveness of these new hybrid multigoal policies is worth examining.

Among the new energy technologies, fuel cells are a viable option for curbing greenhouse gas emissions. A fuel cell is an electrochemical device that converts the chemical energy of hydrogen into electrical energy, with water and heat as by-products (Arshad et al., 2019). Hydrogen can be produced by water electrolysis—a process powered by electricity generated from renewable energy, nuclear, or fossil fuels (U.S. Department of Energy, 2018). Fuel flexibility is a primary advantage of fuel cells. Other advantages include low emissions, electric efficiency greater than 50%, and a diverse variety of applications (U.S. Department of Energy, 2018).

In the United States, fuel cells are deployed across stationary, transportation, and portable power sectors (U.S. Department of Energy, 2018). The widest application is small stationary fuel cells for commercial and government uses. Equipment for handling fuel cell materials had been commercially deployed in several states, such as Alabama, Arizona, California, and Colorado, as of 2017 (U.S. Department of Energy, 2018). On an international scale, the Intergovernmental Panel on Climate Change (IPCC) recognized the potential contribution of fuel cells to power generation, particularly decentralized stationary and mobile hydrogen fuel cells (Intergovernmental Panel on Climate Change, 2000).

However, the development of fuel cells also encounters technical

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challenges and high costs (U.S. Department of Energy, 2015). To strengthen the advantages and reduce the disadvantages, the U.S. federal government has allocated funds and provided incentives to support fuel cell research and development. As of 2019, federal incentives included the Business Energy Investment Tax Credit (ITC) and the Residential Renewable Energy Tax Credit (Fuel Cell and Hydrogen Energy Association, 2019).

State governments also have recently encouraged fuel cell development through initiatives and incentives (U.S. Department of Energy, 2018). As Hart wrote, "State and local officials can promote clean energy-based economic development by offering incentives; nurturing tech-based start-ups; deepening clusters of related industries; substituting local energy resources for imports; and stimulating demand" (Hart, 2019b). To fully harvest the potential benefits of a clean energy economy, a successful business model and the best energy-economic policy practices are needed. This research studies the state-driven fuel cell policy in Delaware, evaluates Delaware's energy-economic policy practices, and suggests policy implications for other regions.

Section 2 of this paper reviews the literature about the linkage between clean energy and economic development and between fuel cells and economic development. Section 3 discusses the data and methodologies used. Section 4 analyzes the case of a fuel cell company, Bloom Energy, and the economic incentives provided by the Delaware government. Section 5 presents research results from energy, economic, and social analyses. Section 6 discusses research findings and concludes with policy implications.

2. Literature review

2.1. Studies of the linkage between clean energy and economic development

Many studies have investigated links between new and renewable energy and national and local economic growth. These studies of clean energy and local economic growth vary in their analytical approach, period of data used, and study area. Most of them focus on renewable energy consumption and economics.

For example, in studies of the so-called "Next 11"[1] countries, economic growth was found to catalyze renewable energy consumption when it was evaluated using parametric and nonparametric causality tests, but bidirectional effects were identified using the Geweke Causality Test (Sinha et al., 2018). Bidirectional causality between economic growth and renewable energy consumption was identified in Asia-Pacific Economic Cooperation countries as well. Bidirectional causality means that energy policies can influence economic growth and vice versa (Zafar et al., 2019). Bidirectional causal associations between renewable energy and GDP, as well as between nonrenewable energy and GDP, have also been identified in 11 net oil-importing countries in the Middle East and North Africa. Furthermore, the long-term elastic effect of renewables on real GDP was found to be larger than that of nonrenewables (Kahia et al., 2017).

The direction of causality depends on the area studied, specifically on their economic structure and policies. In China, bidirectional causality was only identified in one province (Heilongjiang), where economic policies strongly supported renewable energy development and effectively guaranteed economic development. No link between renewable energy and economic growth was found in 16 other provinces (Bao and Xu, 2019). Similarly, no causality between renewable energy and GDP was identified in Turkey (Bulut and Muratoglu, 2018). The causality between economic growth and renewable energy has been primarily investigated by economists, mostly using time series or panel data causality tests that focus on renewable energy consumption and GDP (Bao and Xu, 2019). These types of studies mainly aim to identify the existence of an interlinkage and the causality between renewable energy consumption and economic development.

[1] The Next 11 countries are Bangladesh, Egypt, Indonesia, Iran, South Korea, Mexico, Nigeria, Pakistan, the Philippines, Turkey, and Vietnam. The authors categorized 11 countries into developed, newly developed, and emerging countries. Among these countries, only South Korea fell into the category of developed countries.

Other approaches have been used to estimate the potential economic impact of the deployment of renewables (Jenniches and Worrell, 2019; Keček et al., 2019; Ramos et al., 2019; Wang et al., 2019). For example, Jenniches and Worrell (2019) evaluated the economic and environmental impacts of 280 PV plants with a total capacity of 3.7 MW. Using an input-output analysis, they found that solar PV would generate economic effects equivalent to €3.8 million from 2014 to 2034. These various approaches aimed at measuring the effects of renewable energy on socioeconomic development, such as GDP and employment, based on an assumption of one-way causality from renewable energy consumption to economic development.

Also, many studies have investigated the effectiveness of policy measures such as feed-in tariffs or energy tax credits on the deployment of renewable energy (Frazier et al., 2019; Hitaj and Löschel, 2019). However, as Cox et al. (2019) pointed out, the effectiveness of nonenergy policies, including economic policies, has not attracted much attention from researchers or policymakers. Although a great deal of literature has investigated the interconnection between renewable energy consumption and economic growth, it has not scrutinized the effects of economic policies on clean energy deployment. While the effects of changes in the economic system, such as liberalization and energy-relevant taxes or incentives, were analyzed, the general tax regime was not dealt with from the perspective of this interlinkage (Cox et al., 2019).

2.2. Studies of the linkage between fuel cells and economic development

When it comes to fuel cells, connections have rarely been investigated. Although Wang et al. (2019)'s study would seem to explore the links between "hydrogen-based renewable energy" and economic development based on its title, hydrogen-based renewable energy consumption actually refers to per capita renewable electricity generation, excluding hydrogen energy due to insufficient historical data. Similarly, Xu et al. (2019) investigated the links between economic development and "hydrogen-based renewable energy." Again, that term includes renewable energy and the share of hydrogen energy is negligible. When the regional or national scale impacts of fuel cell technologies have been analyzed, it has been for environmental impacts, not economic aspects (Kendall, 2018).

Instead, most existing studies focus on the economic feasibility or cost analysis of specific fuel cell technologies (Owebor et al., 2019). For example, they focus on the transportation sector (Chen and Melaina, 2019; Hombach et al., 2019; Morrison et al., 2018; Thompson et al., 2018) or on combined heat and power (Löbberding and Madlener, 2019; Napoli et al., 2015).

Morrison et al. (2018) analyzed the competitiveness of fuel cell vehicles, together with electric vehicles. They focused on light-duty vehicles (LDV) and compared the total cost of ownership. They found that fuel cell vehicles would be cost-competitive in the long-term (by 2040) with electric vehicles, especially for large cars with longer travel distances. Chen and Melaina (2019) conducted a similar but more comprehensive study that compared the long-term cost and performance competitiveness of various powertrain technologies, including internal combustion, hybrid, plug-in hybrid, electric, and fuel cell vehicles. Thompson et al. (2018) estimated the manufacturing cost of a fuel cell system for LDVs in 2017, finding that the total system cost ranges from \$45kWnet to \$50kWnet when it is produced at a large volume, 100,000 to 500,000 units per year. However, a cost reduction to \$30/kWnet would be needed to achieve cost parity with internal combustion systems.

The effectiveness of policy measures for fuel cells and the impacts of policy measures on fuel cell deployment or the fuel cell industry have been studied less than the impacts of fuel cells on economic development. For example, Upreti et al. (2016) measured the impacts of the American Recovery and Reinvestment Act (ARRA)[2] and the ITC on the North American fuel cell industry. The authors simulated the impacts of the policy measures using a model that considered learning-by-doing and economies of scale from increased sales of fuel cells. The ARRA will induce additional sales of about 5600 fuel cell units by 2025.

3. Methodology and data

This research combines quantitative and qualitative analysis. For the quantitative analysis, real measurable data were compiled from a variety of sources. This study uses heat rate and efficiency percentage as indicators for energy efficiency calculation and comparison (for detailed information, see Section 5.1.1). The heat rate and efficiency calculation formulas are as follows:

(1) Heat rate = input energy (Btu)/output power (kWh)
(2) Efficiency = 3412 (Btu)/heat rate * 100%

The U.S. Energy Information Administration (EIA) collects power plant performance data annually. This study uses the EIA's 2017 heat rate data as the basis for comparing Bloom Energy's fuel cell efficiency to other power generation technologies (U.S. Energy Information Administration, 2018b). The study calculates the heat rate and energy efficiency of Bloom fuel cells based on operating records that are documented in the DelaFile system maintained by the Delaware Public Service Commission (PSC). This includes monthly natural gas consumption and electricity production.

For economic analysis, this research adopts two indicators: employment and payroll (wages and salaries). Statewide economic data is from the Delaware Bureau of Labor Statistics. Company-level data is from Bloom Energy's quarterly reports, the Form 10-Q mandated by the U.S. Securities and Exchange Commission. Employment data before 2018 (the year Bloom started to submit Forms 10-Q) is from economic news reported by the *Wilmington News Journal*, a Delaware-based news outlet.

The social discussion focuses on the surcharge that is part of the Qualified Fuel Cell Provider (QFCP) Project. Surcharge data is from the monthly reports that Delmarva Power & Light (Delmarva) submitted to the Delaware PSC. This research also collected information from local newspapers (*Wilmington News Journal* and *Delaware Business Now*) and public hearing minutes.

4. Background

4.1. Bloom Energy

Bloom Energy Corporation is a company based in Silicon Valley that manufactures the Bloom energy server, a patented solid oxide fuel cell that converts low-pressure natural gas or biogas into electricity through an electrochemical process (Bloom Energy Corporation, 2010). Bloom Energy claims that its server generates electricity with a high conversion efficiency (53–65%) and produces fewer harmful emissions than conventional fossil fuel generation (Bloom Energy, 2019a). The company's mission is to produce "clean, reliable, and affordable energy for everyone in the world." Bloom Energy has many industry-leading companies as its customers, including Bank of America, Coca-Cola, eBay, FedEx, Google, Staples, and Walmart (Bloom Energy Corporation, 2010).

The Delaware state government has recognized the potential economic and environmental benefits of the clean energy industry. Therefore, it welcomed Bloom Energy to set up its East Coast headquarters in Delaware through four policy instruments: a grant agreement, a rent benefit, a legislative amendment, and a new electricity tariff.

4.2. The incentives

4.2.1. Grant agreement

A grant agreement was made between the Delaware Economic Development Office (DEDO)[3] and Bloom Energy in 2012. It included a $12 million grant that could increase to $16.5 million. This grant required Bloom Energy to create 900 full-time jobs at its manufacturing plant and to spend $12 million on salaries over 12 months by September 2014. DEDO also provided a conditional incentive of $6250 for each additional employee (up to 600) created by suppliers that co-located to the site (Carper, 2011). DEDO also offered to provide 3% of Bloom's total capital expenditures up to the first $50 million (Carper, 2011). Combining all these incentives, DEDO offered Bloom Energy a potential $16.5 million grant. If the job target was unmet or if Bloom did not maintain the jobs, the state had the authority to recapture its investment (Carper, 2011). Delaware Governor Jack Markell defined the Bloom project as economic development, because the primary goal was to invigorate economic growth by establishing a fuel cell industry and creating new jobs in Delaware (Wilmington News Journal, 2014).

4.2.2. Rent benefit

A rent benefit, also called the lease execution grant, was another financial incentive. Bloom Energy planned to establish its manufacturing facility on 50 acres of land at the University of Delaware (UD). Chrysler had owned the land but had shuttered its vehicle manufacturing plant in 2008. UD acquired the property in 2009 and developed a new science and technology campus. Because Bloom Energy's innovative energy manufacturing image matched UD's science and technology planning (Carper, 2011), it received a $1 per year rent contract for 25 years (Mordock and Murray, 2016a). The university also received a $7 million grant from the state to improve infrastructure throughout the entire site (Carper, 2011).

4.2.3. Legislative amendment

Along with financial agreements, Delaware also amended its Renewable Energy Portfolio Standards Act (REPSA) to include fuel cells as an eligible resource. On July 7, 2011, Governor Markell signed these amendments into law. Because of the amendment, Delmarva, the only regulated utility in Delaware after electricity market deregulation (Chen, 2019), can fulfill its renewable credits requirements under REPSA by purchasing electricity generated from fuel cells. The amendments not only gave Delmarva Power a new way to meet its renewable-energy requirement, but they also secured a buyer for Bloom Energy, even though the primary energy source for the fuel cells is natural gas (Delaware PSC, 2019).

4.2.4. New electricity tariff

The most unusual incentive is a special tariff, the QFCP, which is designed to compensate Bloom Energy's costs for power generation. It applies to 30 MW facilities and can scale up to 50 MW. This tariff imposed a 21-year surcharge on Delmarva's ratepayers. The Delaware PSC approved the QFCP in 2011. This surcharge ensured that Bloom

[2] The ARRA funded the deployment of nonautomotive fuel cell systems, such as material handling equipment fuel cell units at facilities and backup fuel cells. This project aims to deploy fuel cells, accelerate commercialization, and promote the fuel cell industry (Kurtz et al., 2012).

[3] The DEDO was an office in the Executive Department of the State. The DEDO was the authority that signed the agreement with Bloom Energy in 2011. The DEDO was replaced by a public-private partnership in 2017, the Delaware Economic Development Agency (DEDA).

Energy would have a predictable revenue stream for 21 years, from the middle of 2012 through 2033 (Bloom Energy Corporation, 2018). To ensure the linkage of cost (tariff) to benefit (job creation), Bloom Energy agreed to make a termination payment to the state if Bloom permanently ceased fuel cell manufacturing in Delaware (Delaware DEDO and Bloom, 2011).

Fig. 1 summarizes the incentives provided by Delaware.[4] In exchange, Bloom Energy agreed to fulfill the following obligations: (1) establish a new manufacturing facility in Delaware; (2) make at least $50 million in allowable capital expenditures to renovate the manufacturing facility; and (3) employ at least 300 full-time workers by 2014, 600 by 2015; 900 by 2016, and maintain a consistent workforce of 900 full time employees until 2023.

In sum, Delaware designed policies to invite Bloom Energy to the state that had three goals: (1) establishing a fuel cell manufacturing industry and making Delaware a new high-tech energy manufacturing hub, (2) creating well-paying middle-class manufacturing jobs and vibrant economic activity, and (3) increasing local power generation and formulating a low-emissions power generation profile (Carper, 2011). The next section evaluates the policy outcomes.

5. Results and discussion

5.1. Results

5.1.1. Energy analysis

Reliability, efficiency, affordability, and cost effectiveness are primary targets for the energy supply business. Fuel cells provide reliable baseload distributed power generation as well as backup power (U.S. Department of Energy, 2018). Fuel cells also efficiently convert primary energy to electricity (U.S. Department of Energy, 2018). This high efficiency is a selling point promoted by Bloom Energy. However, Bloom Energy has been criticized since it entered Delaware because it did not release information on the energy efficiency of its fuel cells (Rainey, 2011).

This section reviews the power generation efficiency of two Bloom facilities in Delaware based on actual natural gas input and electricity output data. Heat rate and efficiency percentage are two indicators for energy conversion efficiency. "Heat rate" means the amount of energy (BTUs) consumed to produce a kilowatt-hour of energy. "Efficiency" is a dimensionless measure (typically quoted in percentage) that is the inverse of heat rate. A lower heat rate indicates better efficiency. The heat rate is used to compare the performance of Bloom servers to fossil fuel-fired generators and nuclear power plants in the United States (U.S. Energy Information Administration, 2018a). The heat rate is then converted to efficiency as a percentage to compare it with renewable technologies.

Table 1 shows the 2017 average operating heat rate and efficiency of various generating technologies and primary energy inputs. Natural gas combined-cycle power plants showed the best performance, with an average heat rate of 7649 Btu/kWh (equivalent to 44.6% efficiency).

The actual generating data from Bloom Energy's two facilities in Delaware is listed in Table 2 and Table 3. The average heat rate is 7600 Btu/kWh (44.89%) at the Red Lion site and 7546 Btu/kWh (45.22%) at the Brookside site. Based on this data, the generating performance of Bloom fuel cells is very competitive with other technologies, particularly considering that fuel cells degrade over time.

It is worth noting that Bloom claimed that its newest model, Energy Server 5, has better efficiency performance than previous models. The heat rate of Energy Server 5 is 7127–5811 Btu/kWh and its cumulative electrical efficiency is 53–65% (Bloom Energy Corporation, 2017a, 2017b). Bloom Energy submitted maintenance upgrade applications to the Delaware Department of Natural Resources and Environmental Control (DNREC) in October 2018 so it could replace old servers with new ones at both sites (Secure America's Future Economy, 2019).

In conclusion, the electricity generating efficiency of Bloom's fuel cells is better than the average efficiency of other fossil fuel-based power plants and nuclear power in the United States. However, generating efficiency will decrease over time because fuel cells degrade,[5] so regular system updates are needed.

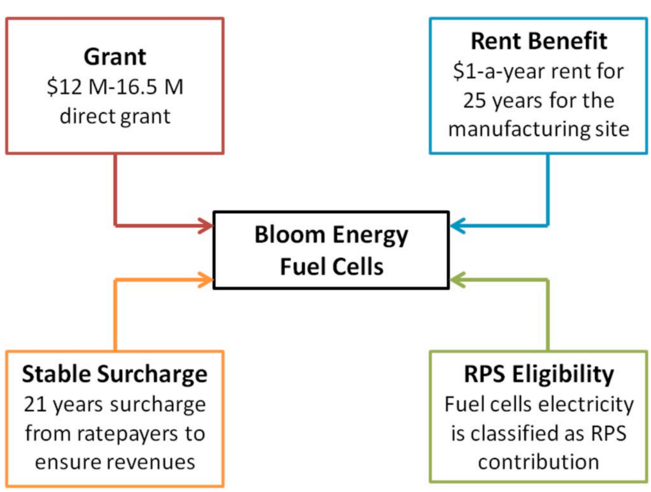

Fig. 1. Incentives Bloom Energy received from Delaware.

5.1.2. Economic analysis

Creating new job opportunities to vitalize the Delaware economy is the primary goal of the Bloom Energy initiatives. Introducing an industry with a new manufacturing facility was expected to create positive economic impacts. This section presents an economic impact analysis of Bloom Energy. Two direct economic measurements are adopted: employment impact and labor income impact. *Employment impact* measures the increase in the total number of employees in the state. *Labor income impact* represents the increase in total money paid to local

Table 1
Average operating heat rate (Btu/kWh) and efficiency (%) for selected energy sources.

Prime mover	Coal	Petroleum	Natural gas	Nuclear
Steam generator	10,043 (33.97%)	10,199 (33.45%)	10,353 (32.96%)	10,459 (32.62%)
Gas turbine	–	13,491 (25.29%)	11,176 (30.53%)	–
Internal combustion	–	10,301 (33.12%)	9120 (37.41%)	–
Combined cycle	W	9811 (34.78%)	7649 (44.62%)	–

(U.S. Energy Information Administration, 2018b).
Note: (1) W = Withheld to avoid disclosure of individual company data. (2) Heat rate is reported at full load conditions for electric utilities and independent power producers. (3) The average heat rates above are weighted by net summer capacity. (4) Coal combined cycle represents integrated gasification units.

[4] The section focuses on incentives provided by Delaware. Bloom Energy subsidiary Diamond State Generation Partners LLC also received a $77 million federal tax credit for their Delaware fuel cell facilities in 2014 under program 1603 of the Recovery Act (Mordock and Murray, 2016a).

[5] The SOFC fuel cells technology has not fulfilled the strict lifetime requirement of over 40,000 h with a power loss less than 10% for stationary allocations (Lee et al., 2018).

Table 2
Red lion site energy performance.

Period	Natural gas usage (CCF)	Electricity output (MWh)	Heat rate (Btu/kWh)	Efficiency
Jan-18	1,285,480	17,418	7528	45.32%
Feb-18	1,163,160	15,707	7554	45.17%
Mar-18	1,282,050	17,203	7601	44.89%
Apr-18	1,248,880	16,755	7603	44.88%
May-18	1,281,440	17,218	7591	44.95%
Jun-18	1,244,730	16,723	7592	44.94%
Jul-18	1,279,700	17,253	7565	45.10%
Aug-18	1,279,680	17,156	7608	44.85%
Sep-18	1,245,400	16,677	7617	44.79%
Oct-18	1,288,070	17,217	7631	44.71%
Nov-18	1,248,410	16,623	7660	44.54%
Dec-18	1,288,050	17,167	7653	44.58%
Average	1,261,254	16,926	7600	44.89%

(Delaware Public Service Commission, 2019b, 2018a; 2018b, 2018c; 2018d, 2018e; 2018f, 2018g; 2018h, 2018i; 2018j, 2018k).

Table 3
Brookside site energy performance.

Period	Natural gas usage (CCF)	Electricity output (MWh)	Heat rate (Btu/kWh)	Efficiency
Jan-18	134,510	1813	7567	45.09%
Feb-18	128,160	1753	7455	45.77%
Mar-18	138,620	1892	7475	45.65%
Apr-18	138,940	1912	7410	46.04%
May-18	142,950	1953	7466	45.70%
Jun-18	135,880	1856	7469	45.68%
Jul-18	136,490	1855	7506	45.46%
Aug-18	136,430	1833	7594	44.93%
Sep-18	134,490	1805	7600	44.90%
Oct-18	139,390	1856	7659	44.55%
Nov-18	134,000	1779	7681	44.42%
Dec-18	137,820	1829	7686	44.39%
Average	136,473	1845	7546	45.22%

(Delaware Public Service Commission, 2019b, 2018a; 2018b, 2018c; 2018d, 2018e; 2018f, 2018g; 2018h, 2018i; 2018j, 2018k).

employees in the form of salaries and wages. This study uses Bloom Energy's payroll expenditures to evaluate the labor income impact in Delaware.

According to the agreement between Bloom Energy and DEDO, Bloom Energy was required to submit annual employment and compensation reports, beginning on October 31, 2012, and continuing through September 30, 2023.

Two types of benchmark were established: employment numbers and compensation. Under the agreement, Bloom Energy had to either create 900 full-time jobs or pay the full-time employees a cumulative total of $108 million in compensation by September 30, 2017, to retain the entire amount of its grant (Bloom Energy, 2019b; Delaware Economic Development Office, 2012). Bloom Energy met neither of the benchmarks, so it returned $1.5 million to the state in 2017 (Baker, 2018a, 2018b; Gross, 2017; Mueller, 2017). The next target year is 2023, when Bloom is benchmarked to employ 900 full-time workers with an accumulated total compensation of $324 million. Table 4 compiles employment and payroll data beginning in 2014, one year after Bloom Energy opened its Delaware manufacturing facility.

Regarding job quality, Bloom Energy offers both high-wage technical and blue-collar manufacturing positions (Mordock and Murray, 2016b). The average Bloom Energy salary in Delaware was $65,000 in 2019. A senior applications engineer at Bloom Energy earned the most, with an average annual salary of $100,879, while an assembly-line worker made the least, with an average annual salary of $32,235 (PayScale, 2019).

Many factors influence the growth of Bloom Energy as a new energy industry, such as the global market and government policies. In Delaware, Bloom Energy met only 30% of the employment target and 50% of

Table 4
Target and actual data for Bloom Energy's hiring and payroll.

	Hiring		Cumulative payroll (millions)	
	Target	Actual	Target	Actual
2014	300	208	$12	$9.5
2015	600	224	$36	$27
2016	900	277	$72	$45
2017	900	302	$108	$64
2018	900	338	$144	$92
2019	900	334	$180	$99.3
2020	900	–	$216	–
2021	900	–	$252	–
2022	900	–	$288	–
2023	900	–	$324	–

Note: Actual data through 2017 is derived from the *News Journal* (Baker, 2018a, 2018b; Gross, 2017; Mueller, 2017); actual data beginning in 2018 is derived from Form 10-Q, a quarterly report Bloom Energy files with the U.S. Securities and Exchange Commission (Bloom Energy, 2019b). Target data is from the agreement between Bloom Energy and DEDO (Delaware Economic Development Office, 2012).

the accumulated payroll target in 2019. However, Bloom Energy brought positive economic impact to Delaware by creating decent-paying jobs and building a fuel cell industry in Delaware. Also, Bloom Energy became listed in the stock exchange in 2018. As a listed company, Bloom Energy is required to file regular financial reports with the federal Securities and Exchange Commission (SEC), which enhances the financial transparency of Bloom Energy to investors, customers, and policymakers.

5.1.3. Social analysis

The Delaware government offered economic incentives that were aimed at building up the fuel cell industry and boosting the state's economy. However, this clean energy-related economic policy has raised concerns about social equity and fairness. A major criticism is the 21 years of cost distribution to Delmarva ratepayers through the special electricity tariff, the QFCP. In addition, the QFCP is complex but the decision-making procedure was quick. This created misunderstandings among policymakers, Bloom Energy, ratepayers, and the public.

The following formula shows how the QFCP is calculated. The contract costs are a specified disbursement rate approved by the Delaware PSC. The rate is $166.87 per MWh for the first 15 years; $102.00 per MWh for the 16th to 20th years; and $30 per MWh for the 21st year. The fuel cost is the amount paid to the PJM (Pennsylvania, Jersey, Maryland Power Pool)[6] for purchasing natural gas as input fuel for the fuel cells. The administrative costs are collected for administrative services, such as bill preparation, and other operation and maintenance (O&M) expenses. The revenue is also called the PJM revenue, which is the amount Bloom Energy received from PJM from electricity and capacity sales.

Monthly QFCP Project Charge = Contract costs + Fuel cost + Administrative cost − Revenue + True up + Banking + Interest

QFCP also includes three adjustment variables: banking, interest, and true-up. Banking and interest are included in the formula but are zero in actual data (Fig. 2). True-up adjusts the differences between projected costs and the actual costs in each billing cycle.

Fig. 2 presents trends in the monthly QFCP charge from June 2012 to March 2019, showing four main patterns. First, contract cost is the major contributor to the QFCP, ranging from 60.8% (October 2012) to 138% (February 2019). The contract cost was based on a fixed disbursement rate determined in the original QFCP legislation. Second, fluctuation in

[6] PJM is a regional transmission organization (RTO) that coordinates the wholesale electricity market in all or parts of 13 states (including Delaware) and the District of Columbia.

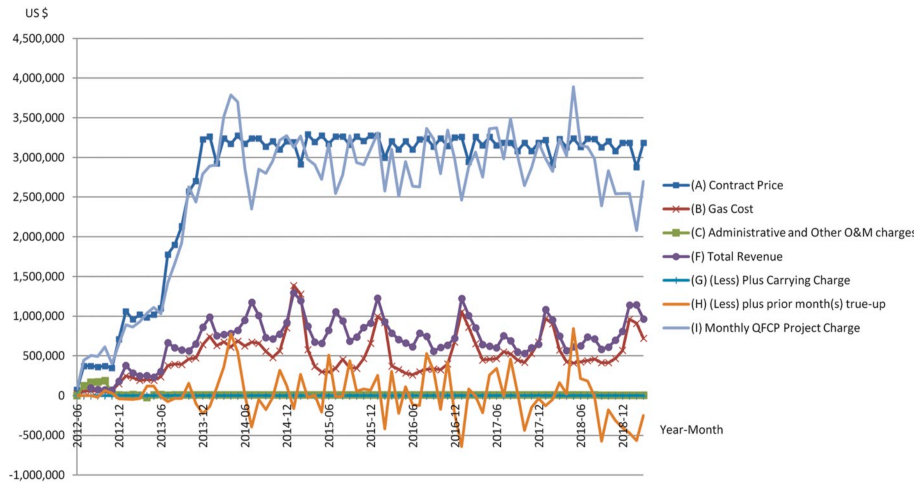

Fig. 2. The QFCP tariff.

the QFCP is primarily derived from the prior month's true-up. Third, the fuel price influences both the gas cost and the total revenue, but in opposite directions. In other words, those two factors have an offset effect in the QFCP calculation. Fourth, administrative and O&M costs comprised a large portion in the beginning (e.g., $187,050 in October 2012), but they decreased to $9000 per month after August 2013 and have been $5000 per month since September 2018.

The QFCP is a usage-based charge: the more electricity a customer consumes, the higher QFCP they need to pay. For a residential ratepayer with an average 1000 kWh monthly usage, the QFCP project surcharge was around $3-$7 per month. The media regularly reported the QFCP surcharge monthly before the surcharge began being listed separately on Delmarva bills in 2015 (Mordock, 2015). After that, the media highlighted the accumulated QFCP (Fig. 3) when its total reached $100 million and $200-million (see Baker, 2018c).

A vigorous debate about QFCP arose. Surcharge skeptics argued that the QFCP was a long-term subsidy to Bloom, one agreed upon by politicians, Bloom Energy, and Delmarva without representation from ratepayers (Heckman, 2014). Skeptics note that Bloom Energy has not increased jobs as much as promised, which was the basis for Delaware's QFCP offer (Rabbitt, 2014).

The chairman of the Delaware PSC clarified the meaning of "cost projection" in an opinion column in the *News Journal* in April 2014 (Winslow, 2014). He explained that the costs in the QFCP surcharge matched the anticipated analysis. Before the PSC passed the QFCP in 2011, two consulting companies evaluated the costs and had similar estimations. They evaluated cost differences between Bloom Energy's fuel cells project and the Bluewater Wind project, an offshore wind power project subsidy under consideration. The evaluation identified the net financial impact, which showed cost differences between the two

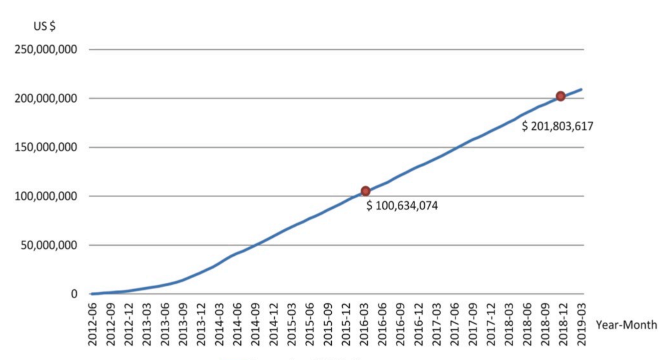

Fig. 3. Accumulated QFCP payments.

projects. Both analyses concluded that Bloom's fuel cells project was more cost effective and had greater renewable energy credit[7] savings. However, the QFCP surcharge shown on ratepayers' bills represented the actual costs of fuel cell electricity, not the net impact. The amount billed was greater than what the consultants' report anticipated; this aroused critics even though these numbers represented two different concepts.

Criticisms of the QFCP came up because of the complexity of the surcharge and the different interpretations of the costs. The public, particularly ratepayers, needed a clear explanation (Nathans, 2014). This misinterpretation of the complex surcharge led to the second social concern: that the quick decision-making procedure had insufficient communication, particularly public participation. The state had granted the financial incentives, passed the REPSA amendments, and approved the QFCP tariff in a very short period. Ratepayers had limited time and opportunity to become aware of, understand, and raise concerns about the tariff and the rest of the plan. Many ratepayers had concerns about the QFCP surcharge and stated that ratepayers had "no chance to vote on this scheme" (Heckman, 2014).

Another argument was that only Delmarva ratepayers shouldered the QFCP burden – other utilities and municipal electric suppliers were unaffected (Mordock, 2015). Because Delmarva is the only utility under PSC's regulation and it was required to meet the REPSA obligation, only Delmarva customers needed to pay the QFCP.

6. Conclusions and policy implications

This study describes how Delaware leveraged various economic development incentives to foster clean energy manufacturing and utilization in the state. Ex-post policy evaluation was conducted based on energy efficiency, job creation, and social perspectives. Research results indicate that while the economic policy jumpstarted new energy usage and manufacturing, it also had unexpected consequences.

Bloom Energy fulfilled its promise to establish a manufacturing plant and two power generation facilities. The Bloom deal initiated Delaware's fuel cell deployment, making it one of nine states with fuel cell manufacturing facilities, a corporate office, and suppliers and installations (U.S. Department of Energy, 2018). Bloom's fuel cells also have competitive efficiency. Data analyzed in this study support this argument. From this perspective, Bloom Energy met its promise to bring cutting-edge energy technology to Delaware.

[7] Delmarva customers are required to acquire a certain number of renewable energy credits each month to encourage renewable energy development in Delaware.

The case of Bloom Energy yields lessons for policy making from economic and social perspectives. Although Bloom Energy built up the fuel cell industry and created decent-paying jobs in Delaware, it did not meet the employment goal. Because Bloom Energy failed to achieve the employment and payroll numbers it had agreed to, it returned $1.5 million to the Delaware government in 2017 (Baker, 2018a, 2018b; Gross, 2017; Mueller, 2017). Bloom Energy is not the first company to receive a government grant and fail to meet employment goals (Boyer and Ratledge, 2016).[8] However, it is the first case in which a government intended to use grants to achieve both job creation and energy transition goals. This case shows the difficulty of implementing a multipurpose policy.

Great social debate has arisen in this case, particularly about the 21-year QFCP surcharge. The surcharge was based on complicated components and calculations and was preferred by the PSC based on comparing its net financial impact with a wind energy project. However, the public did not have enough time or resources to understand this complexity and present their opinions during decision making. Therefore, many arguments were brought up afterwards.

For example, when considering the surcharge along with the grants, the gap between the costs and benefits of this policy seems huge. A news report published in 2016 stated, “Over the last four years, Delawareans have paid nearly $130 million in energy surcharges.” From this viewpoint, it cost ratepayers $470,000 for each job Bloom Energy created in Delaware (in 2016, Bloom Energy created 277 new jobs) (Mordock and Murray, 2016b).

From Bloom Energy’s perspective, however, the company invested over $26 million to build the manufacturing facilities and has paid out over $90 million in payroll. Therefore, Bloom Energy has invested more than the grant money it received from the agreement ($16.5 million). These different perspectives show a lack of consensus about the economic incentives. The media used the surcharge payment (see Fig. 3) to calculate the cost of job creation, while Bloom Energy used the agreed grant amount to highlight the benefits it brought to Delaware.

Negative social perceptions of Bloom Energy is a big loss for the company, the government, the new energy industry, and the entire society. The Bloom Energy debate is continuing in Delaware. A new “Bloom Rebate Petition” was released in March 5, 2020 (see https://bloomrebatepetition.org/), to ask the government to withhold the QFCP surcharge.

Although this study is context-specific, its lessons and applications are broad. Its first policy implication is that a comprehensive impact evaluation, including social acceptance analysis, is necessary and important. This particularly applies when the government provides economic incentives funded by revenue collected from taxpayers and ratepayers.

A second implication recognizes that the new energy industry is less familiar to the public than traditional industries. In this circumstance, decision-making transparency, information broadcasting, and knowledge enhancement are very important. In the Bloom case, information and knowledge gaps led to misunderstandings and misinterpretations, which triggered societal debate. Based on the complex nature of new clean energy technology and electricity rate design, it is necessary to create an education mechanism to help the public and stakeholders become informed.

Thus, a platform for promoting transparent communication among the public, government, and stakeholders is needed. Private stakeholders (including utility companies and clean energy technology companies) should provide relevant information and help the public understand new technology and its impacts from various aspects. State government could act as a facilitator to create opportunities for conversation between the public and the private stakeholders.

[8] For similar cases, please see (William W. Boyer and Edward C. Ratledge, 2016).

A third implication is that policymakers need to consider social perceptions, particularly when the policy imposes long-term social obligations and effects. In this case, ratepayers of a single utility bear the burden of long-term surcharges. This particularly holds when the surcharge calculation is based on a cost comparison with other renewable projects, the costs of which have significantly changed in recent years.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Wei-Ming Chen: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing. **Hana Kim:** Writing - original draft, Writing - review & editing.

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